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Attorney's Docket No.: 28955.1050

REMARKS

Claims 1-25, as amended, remain herein. Claims 1 and 14 have been amended.

Claims 4, 9, 16 and 19 have been canceled without prejudice or disclaimer. Support for the amendments and the new claims may be found throughout the specification. See, e.g., page 38, line 24 – page 39, line 4; page 26, lines 21-26 of the specification and the original claims.

1. The specification has been amended thereby mooted the objections thereto.
2. Claim 19 has been canceled thereby mooted the objection thereto.
3. Claims 1-25 were rejected under 35 U.S.C. § 112, first paragraph, for alleged lack of enablement.

The standard for determining whether a patent specification meets the enablement requirement is whether the experimentation needed to practice the invention is undue or unreasonable. See *Mineral Separation v. Hyde*, 242 U.S. 261, 270 (1916); *In re Wands*, 858 F.2d 731, 737 (Fed. Cir. 1988); MPEP 2164.01. The fact that experimentation may be complex does not necessarily make it undue, if the art typically engages in such experimentation. See *In re Wands*, 858 F.2d at 737; *In re Angstadt*, 537 F.2d 498, 504 (C.C.P.A. 1976); MPEP 2164.01.

Here, applicants claim specific valence electron level, conduction level, and/or energy gap relationships between the light-emitting-layer material, the first dopant, and the second

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dopant. These relationships allow the first dopant and/or the second dopant to capture the holes injected into the light-emitting-layer material (see, e.g., page 11, line 20 to page 12, line 25 of the specification). This achieves an organic electroluminescence element having a high luminance, high efficiency, and a long durability.

The results described above can be achieved with different compounds having different chemical structures as long as the compounds satisfy the claimed valence electron level, conduction level, and/or energy gap relationships. A person of ordinary skill in the art can measure, without undue experimentation, the valence electron levels, conduction levels, and energy gaps of various dopants and light-emitting-layer materials, and select, based on these measurements, select which compounds to use.

The Office Action alleges that there is uncertainty in the values, making it nearly impossible for an individual of ordinary skill in the art to make the full scope of the invention. The Office Action cites alleged discrepancies between EV values in applicants' specification and Sato (IEEE Journal of Selected Topics in Quantum Electronics, vol. 4, no. 1, pp. 40-48) and Adamovich et al. (New Journal of Chemistry, vol. 26, pp. 1171-78), even though the parties allegedly measured the same materials with the same instrument. The Office Action also alleged that applicants' specification does not disclose factors that affect measurements taken, which factors are allegedly disclosed in Laqua et al. (Pure and Applied Chemistry, vol. 60, pp/ 1449-1460). The Office Action alleged that varying these factors results in discrepancies between EG values in applicants' disclosure and Sato and Adamovich et al.

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Values for the valence electron level, conduction level, and/or energy gap may vary slightly depending on the measuring technique used. The Office Action has not established that the alleged discrepancies were not caused by variations in technique. Rather, the Office Action assumes that the measurements differ simply because the experimenter is different. There is no support for this assumption.

The allegation in the Office Action that applicants disclose only a few examples of potential materials suitable for the light-emitting layer material and the dopant materials, (Office Action, p. 3), also fails to establish that undue experimentation would be required. The Federal Circuit has stated eight factors to consider in determining whether a disclosure is enabling. *In re Wands*, 858 F.2d 731. "It is improper to conclude that a disclosure is not enabling based on an analysis of only one of the above factors while ignoring one or more of the others. The examiner's analysis must consider all the evidence related to each of these factors, and any conclusion of nonenablement must be based on the evidence as a whole." See MPEP § 2164.01(a), citing *In re Wands*, 858 F.2d at 737, 740.

The Office Action violates *Wands* by basing its conclusion of undue experimentation on just one factor, the number of working examples. This is an insufficient ground for rejection under 35 U.S.C. § 112, first paragraph, for lack of enablement. The presence of working examples weights against any conclusion that applicants' disclosure is not enabling. One of ordinary skill in the art would have known how to do what applicants' disclosure teaches. Additionally, Laqua shows the substantial number of variables involved in taking measurements such as those applicants describe. And, Laqua confirms that the level of

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ordinary skill was sufficiently high that one skilled in the art would have had no undue difficulty in taking these types of measurements. The evidence in this record related to the *Wands* factors must be considered. Consideration of applicants' specification in light of that evidence demonstrates that applicants' specification provides adequate guidance for measuring the valence electron levels, conduction levels, and energy gaps (see, e.g., page 38, line 24 to page 39, line 6 of the specification). Applicants respectfully request reconsideration and withdrawal of this rejection.

4. Claims 1, 4-7, 10-11, 14, 16-19, and 22-23 were rejected under 35 U.S.C. § 102(b) over Hatwar U.S. Patent 6,475,648, with evidence allegedly supplied by Shi et al. (Applied Physics Letters, vol. 80, no. 17).

Claim 1, as amended, claims an organic electroluminescence element including a light-emitting-layer material, a first dopant and a second dopant that satisfy the following relations:

(A) $EV0 > EV1$ and $EV0 > EV2$

(B) $EC0 \geq EC2$

(C) $EG0 > EG1 \geq 2.6$ eV and $EG0 > EG2 \geq 2.6$ eV, wherein the valence electron levels are measured with a photoelectron spectroscopic instrument in air and the energy gaps are measured based on an absorption spectrum with a ultraviolet-visible spectrophotometer.

Claim 14, as amended, claims an organic electroluminescence element including a light-emitting-layer material, a first dopant and a second dopant that satisfy the following relations:

(A') $EV0 > EV1$ and $EV0 > EV2$

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(B') $EC0 \geq EC1$ and $EC0 > EC2$, wherein the valence electron levels are measured with a photoelectron spectroscopic instrument in air and the energy gaps are measured based on an absorption spectrum with a ultraviolet-visible spectrophotometer.

The Office Action alleges that Hatwar discloses an electroluminescence element (ADN), including a light-emitting layer material and first dopant (DCJT-B) and second dopant (NPB) of formulas shown in page 7 of the Office Action, and EV, EC, and EG values for the first and second dopant. The Office Action admits that Hatwar does not disclose EV, EC, or EG values for ADN and thus imports these numbers from Shi et al. Federal Circuit has stated repeatedly that, in order to demonstrate anticipation, "the four corners of a single, prior art document [must] describe every element of the claimed invention." See *Xerox Corp. v. 3Com Corp.*, 458 F.3d 1310, 1322 (Fed. Cir. 2006). Here, Hatwar admittedly does not disclose every element of the claimed invention, and thus is not an appropriate basis for an anticipation rejection under 35 U.S.C. § 102(b). Reconsideration and withdrawal of this rejection are respectfully requested.

5. Claims 1, 2, 4-11, 13-14, 16-23 and 25 were rejected under 35 U.S.C. § 102(b) over Sakai Published Patent Application 2002/0136922 (Sakai '922) with evidence allegedly supplied by Sakai U.S. Patent 6,224,966 (Sakai '966) and Hosokawa U.S. Patent 7,087,322 ("Hosokawa '322"). The Office Action alleges that Sakai '922 discloses a light-emitting layer material (bisanthracene compound 6-1), a first dopant (DPVDPAN), and a second dopant (DMPAVB). However, the Office Action admits that Sakai '922 does not disclose EV, EC, or EG values for these compounds and thus imports this information from Sakai '966, Hosokawa

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'322, and even applicants' own specification. As explained above, anticipation requires that each element of applicants' claims be disclosed in a single reference. The Office Action, to the contrary, attempted to combine four different documents (including applicants' own specification) as the basis for the rejection under 35 U.S.C. § 102(b) over Sakai '922. Sakai '922 is no basis for an anticipation rejection. Reconsideration and withdrawal of this rejection are considered.

6. Claims 1, 3-7, 9-10, 13-19, 21-23 and 25 were rejected under 35 U.S.C. § 102(b) over Fukuoka PCT Pub. No. WO 2001/48116, based on English language equivalent U.S. Patent 6,803,120, with evidence allegedly supplied by Hosokawa et al. (Applied Physics Letters, vol. 67, no. 26, pp. 3853-55) ("Hosokawa APL") and Rost et al. (Synthetic Metals, vol. 146, pp. 237-41).

Again, the Office Action relies on multiple references as the basis for rejecting applicants' claims as being anticipated, even though every element must be disclosed by a single document. Fukuoka is not an appropriate basis for rejection under 35 U.S.C. § 102(b). Also, the Office Action admits that $EG1 = 2.08$, thus relation (C) in claim 1 is not met. The Office Action also admits that $EC0 (2.8)$ is not greater than $EC1 (2.9)$, thus relations (B') in claim 14 is not met. Reconsideration and withdrawal of this rejection is respectfully requested.

7. Claims 8, 11, 12, 20, 23 and 24 were rejected under 35 U.S.C. § 103(a) over Fukuoka based on English language equivalent U.S. Patent 6,803,120, with evidence allegedly

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supplied by Hosokawa et al. (Applied Physics Letters, vol. 67, no. 26, pp. 3853-55) and Rost et al. (Synthetic Metals, vol. 146, pp. 237-41), and further in view of Sakai U.S. Patent 6,214,481 ("Sakai '481").

Fukuoka is distinguished above, and the Office Action does not allege that Sakai '481 discloses or suggests applicants' claimed light-emitting layer material, first dopant, and second dopant. Thus, neither Fukuoka nor Sakai '481, nor anything else in the record, discloses all elements of applicants' claimed invention, and these references do not disclose anything that would have suggested applicants' claimed invention to one of ordinary skill in the art. Further, there is no disclosure or teaching in either Fukuoka or Sakai '481, or otherwise in this record, that would have suggested the desirability of combining any portions thereof effectively to anticipate or suggest applicants' presently claimed invention. For all the foregoing reasons, applicants respectfully request reconsideration and withdrawal of this rejection and allowance of all claims 8, 11, 12, 20, 23 and 24.

8. Claims 1-25 were rejected under 35 U.S.C. § 103(a) over Sakai '966 in view of Hosokawa U.S. Patent 5,536,949 ("Hosokawa '949").

Claim 1, as amended, claims an organic electroluminescence element including a light-emitting-layer material, a first dopant and a second dopant that satisfy the following relations:

(A) $EV0 > EV1$ and $EV0 > EV2$

(B) $EC0 \geq EC2$

(C) $EG0 > EG1 \geq 2.6 \text{ eV}$ and $EG0 > EG2 \geq 2.6 \text{ eV}$.

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Claim 14, as amended, claims an organic electroluminescence element including a light-emitting-layer material, a first dopant and a second dopant that satisfy the following relations:

(A') $EV0 > EV1$ and $EV0 > EV2$

(B') $EC0 \geq EC1$ and $EC0 > EC2$.

The Office Action admits that Sakai '966 fails to disclose any example of an organic electroluminescent element having a light-emitting layer material and two dopants. (Office Action, page 16; Sakai '966, Example 1, col. 48, line 40 – col. 49, line 40.) Likewise, Hosokawa discloses using only one dopant, which can include a charge injection auxiliary material and functions as a fluorescent substance. (Hosokawa, col. 27, lines 49-51.) Thus, neither Sakai '966 nor Hosokawa nor anything else in this record discloses an organic electroluminescent element including a light-emitting layer material and two dopants. And, there is no suggestion that one of ordinary skill in the art would be motivated by Hosokawa to modify the single-dopant example of Sakai '966 by adding another dopant because Hosokawa itself discloses using only one dopant. Thus, there is no disclosure or teaching in either Sakai '966 or Hosokawa or anything else in this record that would have suggested the desirability of combining any portions thereof effectively to anticipate or suggest applicants' presently claimed invention. Accordingly, reconsideration and withdrawal of this rejection are respectfully requested.

Additionally, the Office Action relies on EV, EC, and EG values taken from applicants' specification because they are allegedly "similar" to the substances described in Sakai '966 and Hosokawa. Applicants' specification is not prior art and thus is an improper basis for a rejection.

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under 35 U.S.C. § 103(a). Further, the values in applicants' specification are admittedly only estimates. Reported values of EV, EC, and EG for DPAVBi are stated in Yang et al. (J. Applied Physics, vol. 100 at 08311) (Appendix A), submitted herewith. For DPAVBi, Yang discloses the following values: EV1, EV2 = 5.9; EC1, EC2 = 2.8; EG1, EG2 = 3.1. Using these values, none of relations (A)-(C) of claim 1 or relations (A')-(B') of claim 14 is satisfied. For this additional reason, applicants respectfully request reconsideration and withdrawal of this rejection.

9. Claims 1-7, 9-19 and 21-25 were rejected under 35 U.S.C. § 103(a) over Kobori U.S. Patent 6,285,039.

Claims 1 and 14, as amended, each claims first and second dopants each comprising 20 wt% or less of the total weight of the light-emitting layer. However, Kobori discloses that its hole transporting layer (allegedly corresponding to applicants' component 2), is a "host material." (Office Action, p. 19.) A person of ordinary skill in the art would not consider a "host material" to comprise 20 wt% or less of the light-emitting layer. Also, Kobori Example 1 discloses that the electron transporting layer, the hole transporting layer (allegedly applicants' first dopant), and dopant (allegedly applicants' second dopant) are provided in films having thicknesses in a ratio of 50:50:1.5. Thus, the wt% of Kobori's hole transporting layer is unquestionably greater than 20 wt%.

When the contents of dopants are larger, as allegedly disclosed in Kobori, contacting between the dopants causes quenching, which is deleterious to the durability of the EL device. (Specification, p. 14, lines 1-8.) Thus, one of ordinary skill in the art would not consider

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Kobori's hole transporting layer to be analogous to applicants' first dopant, and even if it were so considered, the disclosed weight % is much too great. Thus, Kobori does not disclose all elements of applicants' claimed invention. Furthermore, Kobori discloses nothing that would have suggested applicants' claimed invention to one of ordinary skill in the art. There is no disclosure or teaching in Kobori, or otherwise in this record, that would have suggested the desirability of modifying any portions thereof effectively to anticipate or suggest applicants' presently claimed invention. Accordingly, reconsideration and withdrawal of this rejection are respectfully requested

10. Claims 8 and 20 were rejected under 35 U.S.C. § 103(a) over Kobori and further in view of Hosokawa U.S. Patent 6,743,948 ("Hosokawa '948"). Kobori is distinguished above, and the Office Action did not allege that Hosokawa '948 discloses or suggests applicants' claimed light-emitting layer material, first dopant, and second dopant. Thus, neither Kobori nor Hosokawa '948 discloses all elements of applicants' claimed invention, and neither of these references, nor anything else in this record, discloses anything that would have suggested applicants' claimed invention to one of ordinary skill in the art. Further, there is no disclosure or teaching in either Kobori or Hosokawa '948, or otherwise in this record, that would have suggested the desirability of combining any portions thereof effectively to anticipate or suggest applicants' presently claimed invention. For all the foregoing reasons, applicants respectfully request reconsideration and withdrawal of this rejection.

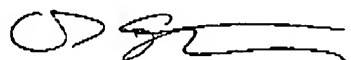
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Accordingly, this application is now fully in condition for allowance and a notice to that effect is respectfully requested. The PTO is hereby authorized to charge/credit any fee deficiencies or overpayments to Deposit Account No. 19-4293 (Order No. 28955.1050). If further amendments would place this application in even better condition for issue, the Examiner is invited to call applicants' undersigned attorney at the number listed below.

Respectfully submitted,

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Date: February 12, 2009



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APPENDIX A

JOURNAL OF APPLIED PHYSICS 100, 083111 (2006)

Stable and highly bright white organic light-emitting diode based on 4,4',4''-tris(N-3-methylphenyl-N-phenyl-amino)-triphenylamine

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(Received 19 February 2006; accepted 2 August 2006; published online 27 October 2006)

A stable and very bright white organic light-emitting diode (WOLED) was fabricated with the structure ITO/m-MTDATA (30 nm)/NPB (30 nm)/DPVBi (11 nm)/Alq₃:DCJTB(50 nm)/LiF (1 nm)/Al (250 nm). White light emission was achieved by combining blue and orange emissions emitted from DPVBi and Alq₃:DCJTB layers, respectively. Inserting an m-MTDATA layer between ITO and NPB improved the charge balance in the recombination zone, improving the stability of the emission color of WOLED. The maximum luminance was 20 590 cd/m² at 13 V with CIE coordinates of $x=0.30$, $y=0.31$. The maximum power and current efficiencies were 6.01 lm/W at 5 V and 6.2 cd/A at 5 V, respectively. Conversely, the WOLED without an m-MTDATA buffer layer exhibited unstable emission characteristic. © 2006 American Institute of Physics. [DOI: 10.1063/1.2360153]

I. INTRODUCTION

Pople (1963) conducted pioneering research on organic electroluminescence (EL) in which he applied hundreds of volts to anthracene crystal to observe the luminescence. However, the findings were of little value at that time, because the voltage requirement was high and the luminescence efficiency was low. In 1987, Tang and VanSlyke of Kodak manufactured a double-layer organic light-emitting diode (OLED) by vacuum evaporation, with markedly improved performance.¹ The performance was enhanced by the effective electron-hole recombination, and the green electroluminescent emission which was confined in the diamine and tris-(8-hydroxy-quinolinato)-aluminum (Alq₃) interface. Organic electroluminescence devices, especially white OLEDs, have attracted much attention because of their potential applications in full color displays with color filter or as backlights and illuminants.²⁻⁴ They have the advantages of a short response time, a wide angle of vision, a simple fabrication process, a low turn-on voltage, a high luminescence efficiency, and a low power dissipation.^{5,6} However, the stability of emission color, and the luminance of white OLEDs (WOLEDs) must be improved for practical use. Accordingly, this study presents the electroluminescence of a stable and very bright WOLED based on a 4,4',4''-tris(N-3-methylphenyl-N-phenyl-amino)-triphenylamine (m-MTDATA) buffer layer. The organic substances 4,4'-bis(2,2-diphenyl-ethen-1-yl)-diphenyl (DPVBi), Alq₃ and 4-(dicyanomethylene)-2-tert-butyl-6-(1,1,7,7-tetramethyljulolidin-4-yl-vinyl)-4H-pyran (DCJTB) were used as blue, green, and red emitting materials, respectively. N, N'-di(naphthalene-1-yl)-N,N'-diphenyl-benzidine (NPB)

was used as the hole-transporting material. Herein, DPVBi emits strong fluorescence in the blue region, and has a good film forming capacity because of its nonplanar molecule structure.^{7,8} DCJTB has excellent chemical stability and chromaticity, and Alq₃ is a preferred material for making emitting and electron-transporting layers.⁹ Additionally, NPB, which is easily synthesized and sublimed, is extensively used as a hole-transporting material. Meantime, the biphenyl structure of NPB contributes to the high electroluminescence efficiency and operational stability of the OLED. Moreover, the m-MTDATA has advantages of low ionization potential (~5.1 eV), superior hole transport capacity, and low leakage current.^{10,11} Therefore, the ITO/m-MTDATA interface can provide the trap-free space-charge-limited (SCL) current at the voltages used in OLEDs.¹² This investigation discusses the effect of the m-MTDATA layer on the emission property of WOLED. Finally, the variations of the stability of the emission color and the luminance of WOLED with the bias voltage were measured and analyzed.

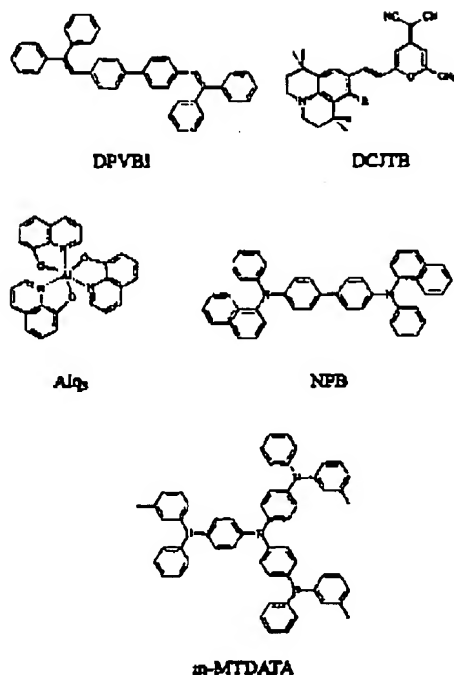
II. EXPERIMENTAL

Figure 1 presents the chemical structures of organic materials used in this investigation for fabricating white organic light-emitting diode (WOLED). DPVBi, Alq₃ and DCJTB were selected as blue, green, and red emitting materials, respectively. NPB and m-MTDATA were used as the hole-transporting and buffer layer materials, respectively. An ITO-coated glass with a resistivity of 15 Ω/\square was used as the starting substrate. The ITO surface was cleaned with an organic solvent and then dried with highly pure nitrogen gas. It was then treated with UV-ozone for 25 min. All organic materials were subsequently evaporated at a deposition rate of 0.5–1 Å/s in a high vacuum (about 10⁻⁶ Torr) to prevent

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FIG. 1. Chemical structures of DPVBi, DCJTb, Alq₃, NPB, and m-MTDATA.

atmospheric moisture and oxygen from permeating the process chamber. The thickness of the deposited films was monitored *in situ* using an oscillating quartz thickness monitor. Finally, the Al cathode was vapor-deposited onto the organic film at a deposition rate of 3 to 4 Å/s in a background pressure of 10^{-6} Torr. The essential structure of WOLED was ITO/NPB (30 nm)/DPVBi (11 nm)/Alq₃:DCJTb (50 nm)/LiF(1 nm)/Al(250 nm) (Device1). Another device was made with the structure ITO/m-MTDATA (30 nm)/NPB (30 nm)/DPVBi(11 nm)/Alq₃:DCJTb (50 nm)/LiF (1 nm)/Al (250 nm) (Device2) to compare the emission property. The CIE coordinates and EL spectra of the devices were measured using a PR650 spectra scan spectrometer and the current-voltage-luminescence characteristics were simultaneously measured by a Keithley 2400 programmable voltage-current source. All the measurements were made at room temperature in air with devices not being encapsulated.

III. RESULTS AND DISCUSSION

Figure 2 shows the energy-level diagram of the WOLED. The highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) of each layer in the WOLED structure are aligned with each other.^{13,14} White emission was obtained by combining blue emission from DPVBi with orange emission from Alq₃:DCJTb. In this situation, Alq₃ not only emitted its own green light but also partially transferred its excitation energy to DCJTb for red emission. Therefore, orange emission from Alq₃:DCJTb was achieved. The dopant concentrations of Alq₃ and DCJTb must be optimized to yield the desired

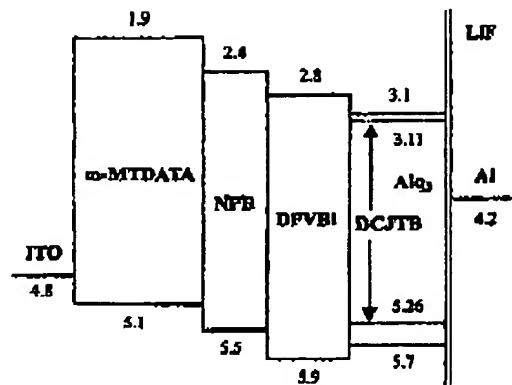
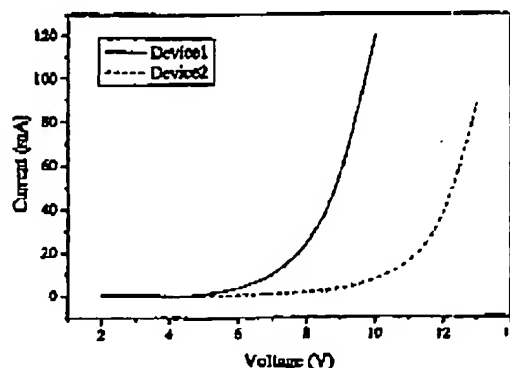


FIG. 2. Energy-level diagram of the WOLED.

emission color. A high DCJTb concentration resulted in low efficiency because of the high concentration quenching effect of the aggregation of the dopants. In this work, optimal orange emission was obtained when the deposition rate ratio of Alq₃ to DCJTb was 1:0.01.

The devices were not encapsulated at the HL property measurements. Figure 3 plots the current-voltage (*I*-*V*) characteristic curves of Device1 and Device2. The turn-on voltage of Device2 exceeded that of Device1, because a 30 nm thick m-MTDATA layer was formed in Device2. However, the m-MTDATA buffer layer decreased the injection of holes from ITO to NPB. Consequently, the carrier balance in the recombination zone and the stability of the WOLED were improved.^{15,16} In contrast, for the WOLED without a m-MTDATA layer (Device1), the accumulation of positive space charges near the ITO contact increased with voltage, causing dielectric breakdown.¹⁷

Figure 4 shows the luminescence-voltage (*L*-*V*) characteristic scheme of Device1 and Device2. The maximum luminance of Device1 and Device2 were 23 090 cd/m² at 10 V and 20 590 cd/m² at 13 V, respectively. The luminescence was higher because almost all of the electrons and holes recombined in the emission layer, even in the WOLED without any blocking layer. The emission colors of Device1 and Device2 were also measured. Figure 5(a) presents the CIE coordinates of Device1. Device1 emitted white light

FIG. 3. Current-voltage (*I*-*V*) characteristic curves of Device1 and Device2.

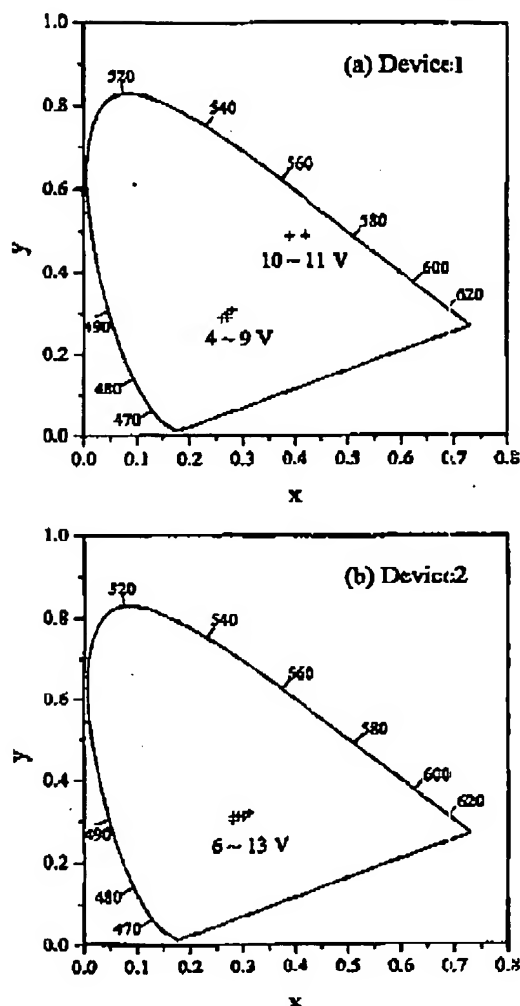


FIG. 5. CIE coordinates of (a) Device1, and (b) Device2 for different bias voltages.

Figure 6 displays the EL spectra of Device2 biased at various voltages. The EL intensity of the WOLED increased with the voltage, and the ratio of blue to orange intensities remained virtually constant as the bias voltage was increased. The high color stability and high luminance of

TABLE I. EL property of Device1 and Device2 at different voltage, and electric fields.

| Device1 (thickness=92 nm) | | | Device2 (thickness=122 nm) | | |
|---------------------------|--------------------------------------|----------------|----------------------------|--------------------------------------|----------------|
| Voltage (V) | Electric field ($\times 10^6$ V/cm) | Emission color | Voltage (V) | Electric field ($\times 10^6$ V/cm) | Emission color |
| 9 | 0.098 | white | 9 | 0.074 | white |
| 10 | 0.108 | orange | 10 | 0.082 | white |
| 11 | 0.119 | orange | 11 | 0.090 | white |
| 12 | | | 12 | 0.098 | white |
| 13 | | | 13 | 0.107 | white |

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TABLE II. CIE coordinates of WOLED of Device1 and Device2 for different bias voltages.

| Bias voltage (V) | Device1 | | Device2 | |
|------------------|---------|------|---------|------|
| | x | y | x | y |
| 4 | 0.27 | 0.29 | | |
| 5 | 0.25 | 0.29 | | |
| 6 | 0.25 | 0.29 | 0.31 | 0.32 |
| 7 | 0.27 | 0.30 | 0.30 | 0.31 |
| 8 | 0.27 | 0.30 | 0.29 | 0.31 |
| 9 | 0.28 | 0.31 | 0.29 | 0.31 |
| 10 | 0.42 | 0.49 | 0.28 | 0.30 |
| 11 | 0.39 | 0.49 | 0.28 | 0.31 |
| 12 | | | 0.29 | 0.31 |
| 13 | | | 0.30 | 0.31 |

WOLED were referred to the optimal thickness of the organic layers, an appropriate ratio of Alq₃ and DCJTB dopants, and improved charge balance in the recombination zone when m-MTDATA was inserted between ITO and NPB layers. The picture of the performance of WOLED (Device2) is shown in Fig. 7.

IV. CONCLUSIONS

A stable and very bright white-emitting OLED (WOLED) was fabricated with an ITO/m-MTDATA (30 nm)/NPB (30 nm)/DPVBi (11 nm)/Alq₃:DCJTB (50 nm)/Al (250 nm) structure. Although the maximum luminance of the WOLED without an m-MTDATA layer reached 23 090 cd/m² at 10 V, the CIE coordinates were shifted to x=0.42, y=0.49. A highly efficiency WOLED with m-MTDATA as a buffer layer inserted between ITO and NPB reduced the hole injection rate from the ITO anode to the NPB transporting layer, improving the charge balance in the recombination zone, and increasing the stability and lu-

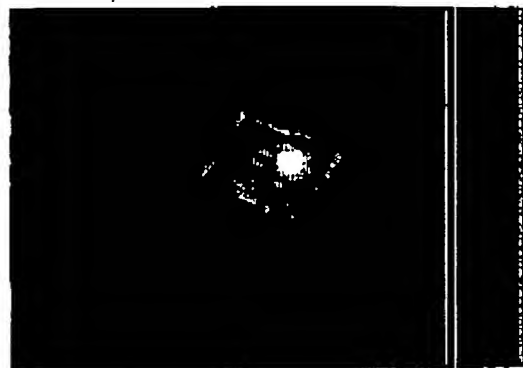


FIG. 7. (Color) Picture of the performance of WOLED (Device2).

minance of the WOLED. A maximum luminance of 20 590 cd/m² and CIE coordinates at x=0.30, y=0.31 were obtained when the bias voltage was at 13 V. Maximum power and current efficiencies of 6.01 lm/W at 5 V and 6.2 cd/A at 5 V, respectively, were achieved.

ACKNOWLEDGMENT

The authors would like to thank the National Science Council of the Republic of China, Taiwan, for financially supporting this research under Contract No. NSC 93-2622-E-151-018-CC3.

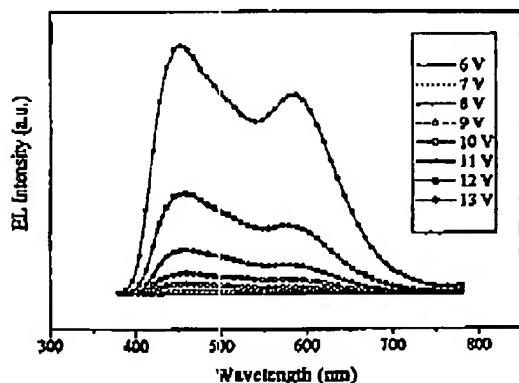


FIG. 6. EL spectra of Device2 biased at different voltages.

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